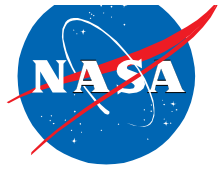

Aircraft Trajectory Design Based on Reducing the Combined Effects of Carbon-di-oxide, Nitrogen and Contrails

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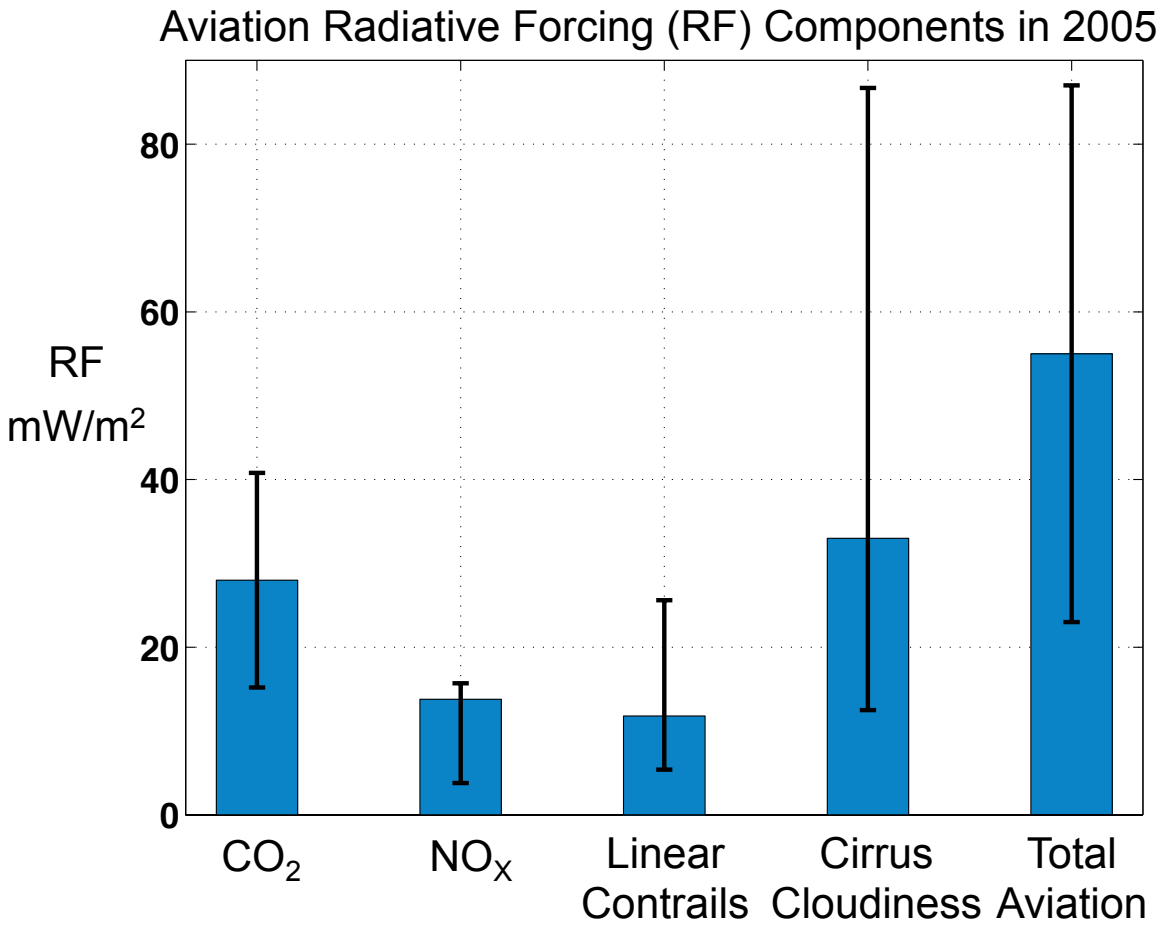
MIT Student and Staff Presentation
Cambridge, MA
May 7, 2014

Impact of Aviation on Climate Change

- Aviation responsible for ~3.5% of all anthropogenic radiative forcing

- Climatic changes
  - Direct emissions: CO_2 , Water vapor
  - Indirect effects: NO_x affecting distributions of Ozone and Methane
  - Contrails and cirrus cloud formation
- Uncertainty in the understanding of the impact of aviation on climate change



D.S. Lee et al, Atmospheric Environment, 2009

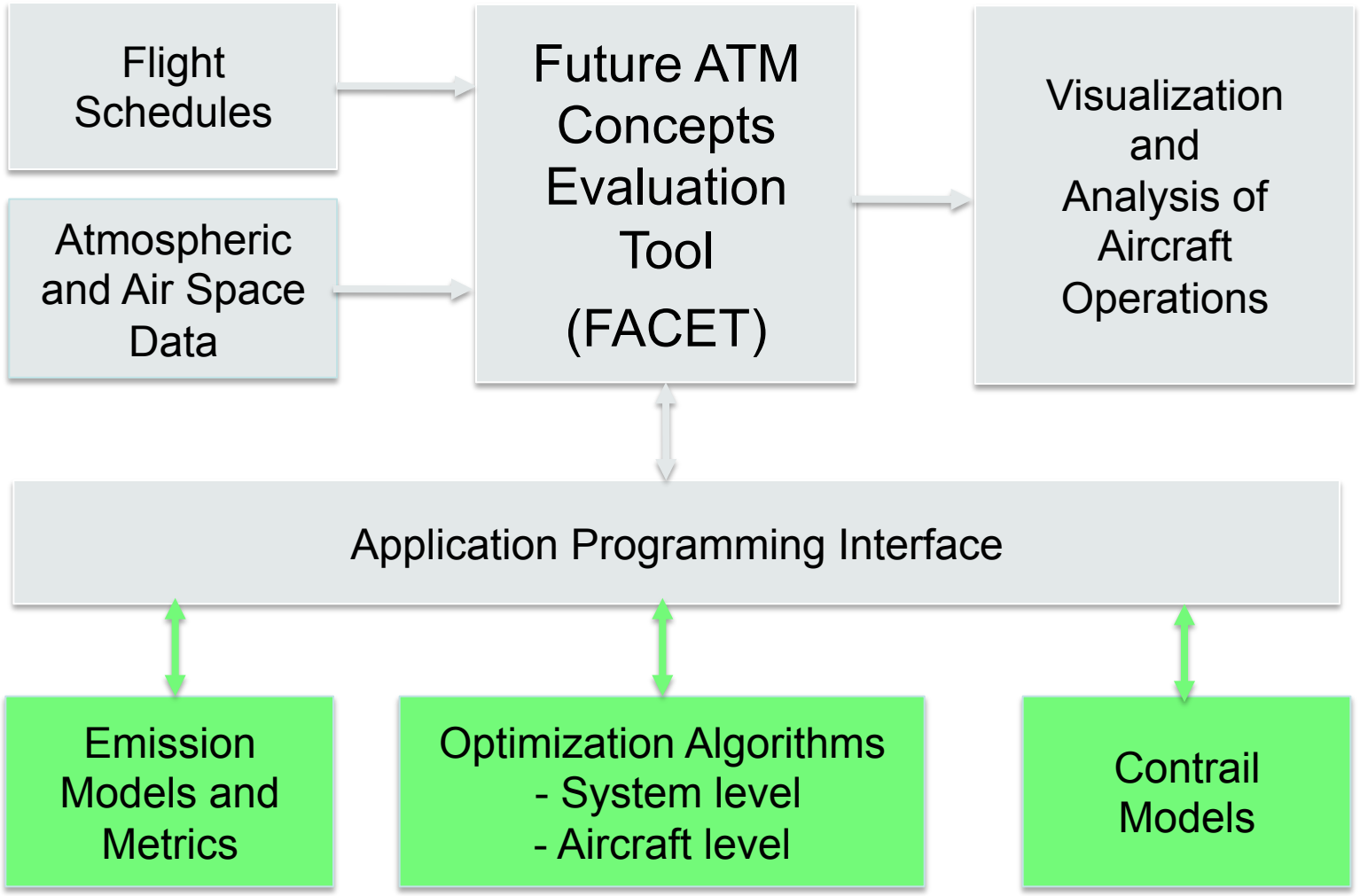
Why is it Hard and What is New in this Paper?

- Analysis of concepts to reduce the impact of aviation and climate requires models of aviation operations, emissions, climate models and metrics
  - Time variation from minutes to decades, spatial variation from local to global
  - Uncertainties in climate models and atmospheric variations
  - Appropriate level of modeling and computationally efficient algorithms to support operations and policy
- Contributions of this paper
  - Modeling of NO_X
  - Development of aircraft trajectory designs minimizing the combined effects CO_2,NO_X and contrails
  - Evaluate the combined effect as a function of time horizon

Outline

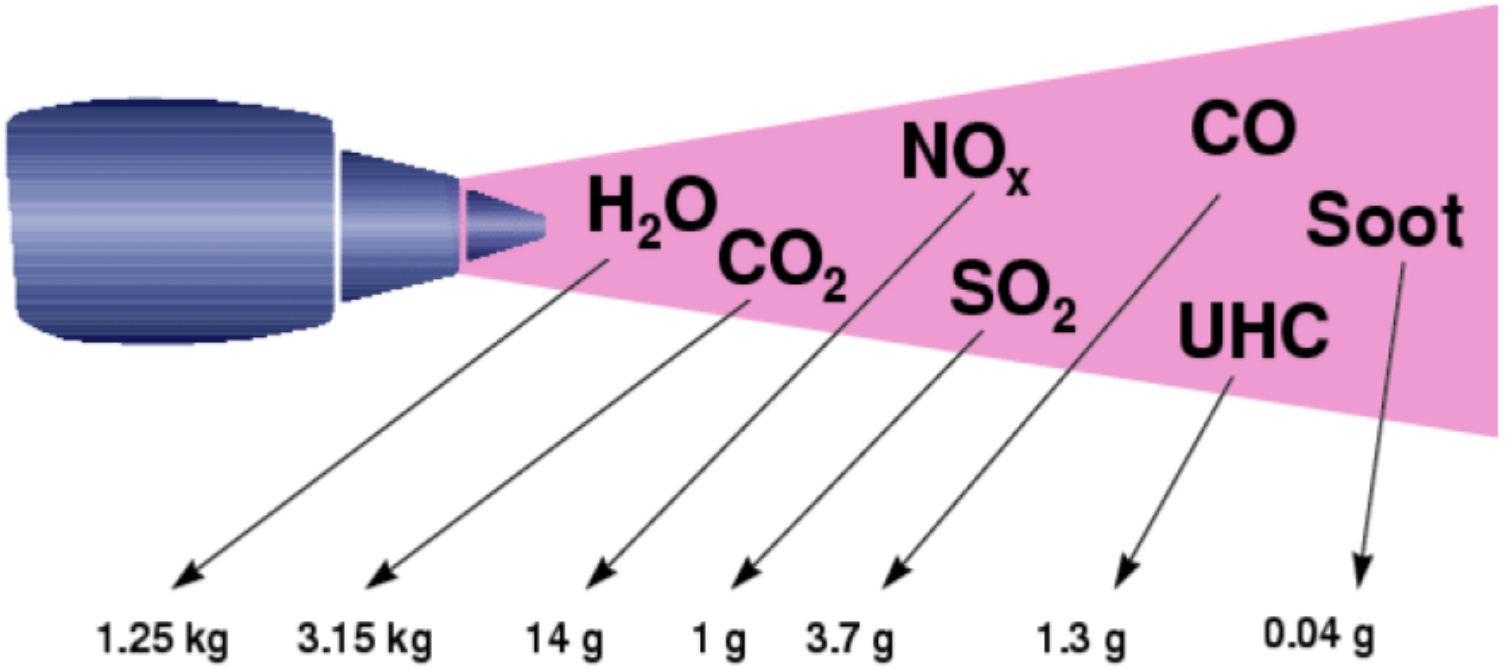
- Aircraft, emissions and contrails models
- Efficient emission reduction concepts
- Effect of time horizon
- Impact of NO_X
- Concluding remarks

Approach


Flight Schedules
Atmospheric and Air Space Data
Future ATM Concepts Evaluation Tool (FACET)
Visualization and Analysis of Aircraft Operations
Application Programming Interface
Emission Models and Metrics
Optimization Algorithms - System level - Aircraft level
Contrail Models

Fuel and Emission Models

Emissions per kg of aviation fuel

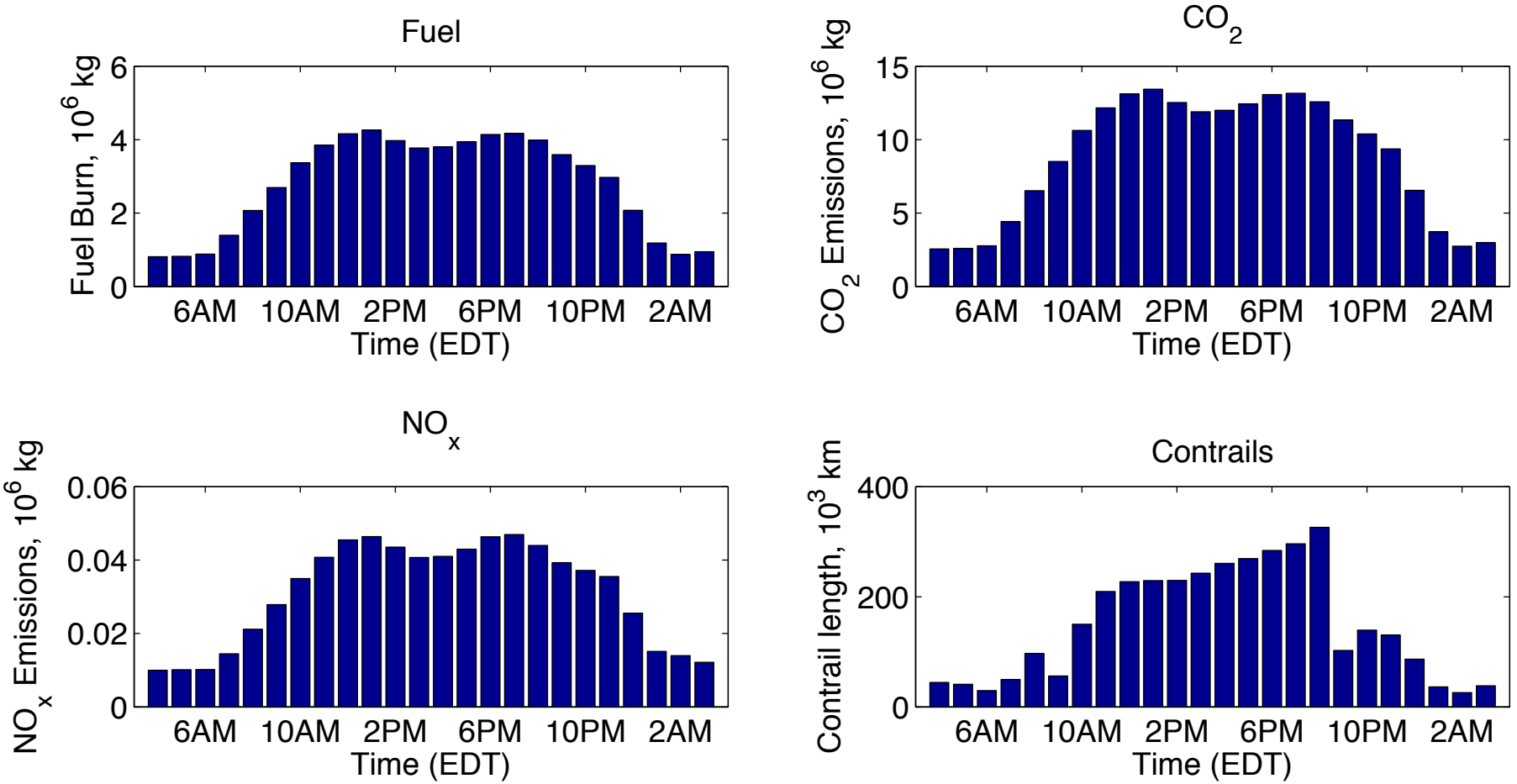


- Eurocontrol's Base of Aircraft Data (BADA)
- FAA Aviation Environmental Design Tool (AEDT)

Contrails

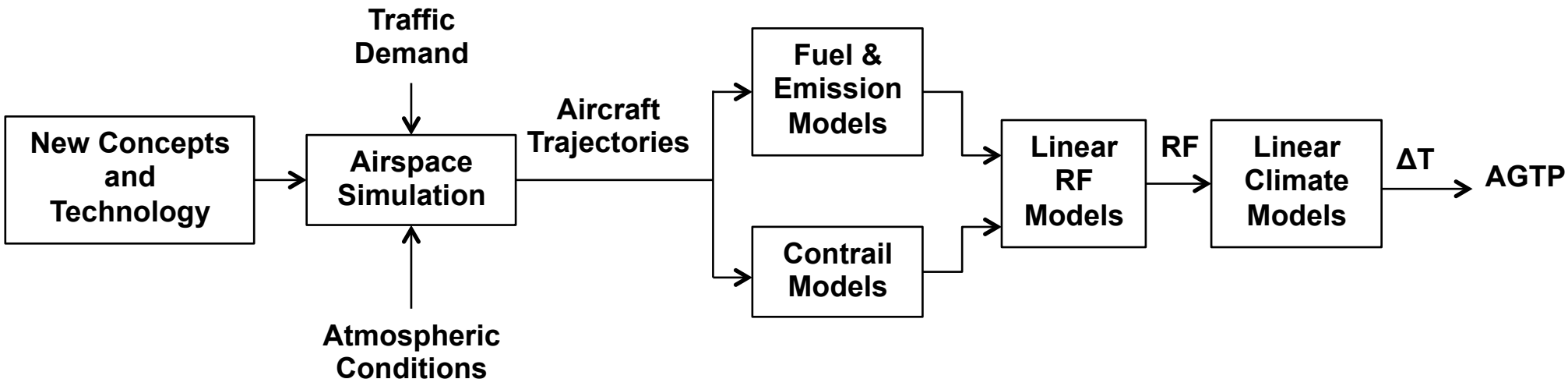
- Occur when warm engine exhaust gases and cold ambient air interact under favorable temperature and humidity conditions

Typical Daily Aircraft Fuel Consumption and CO_2, NO_X and Contrails Production in US



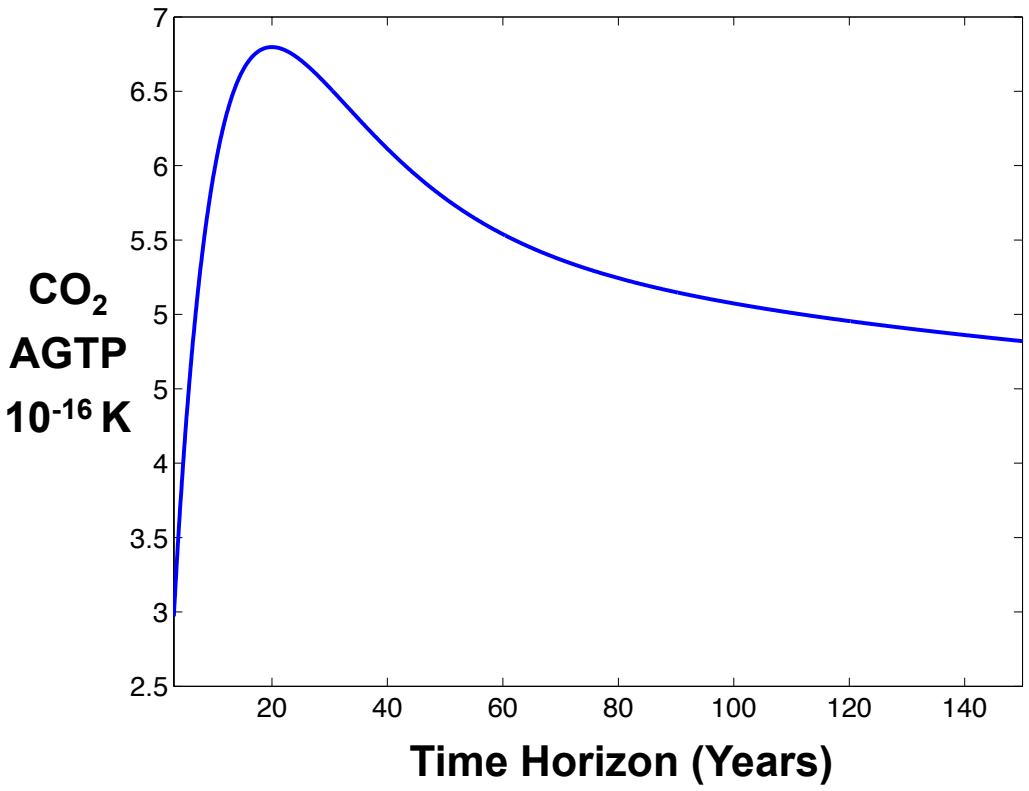
Linear Climate Models and Metrics

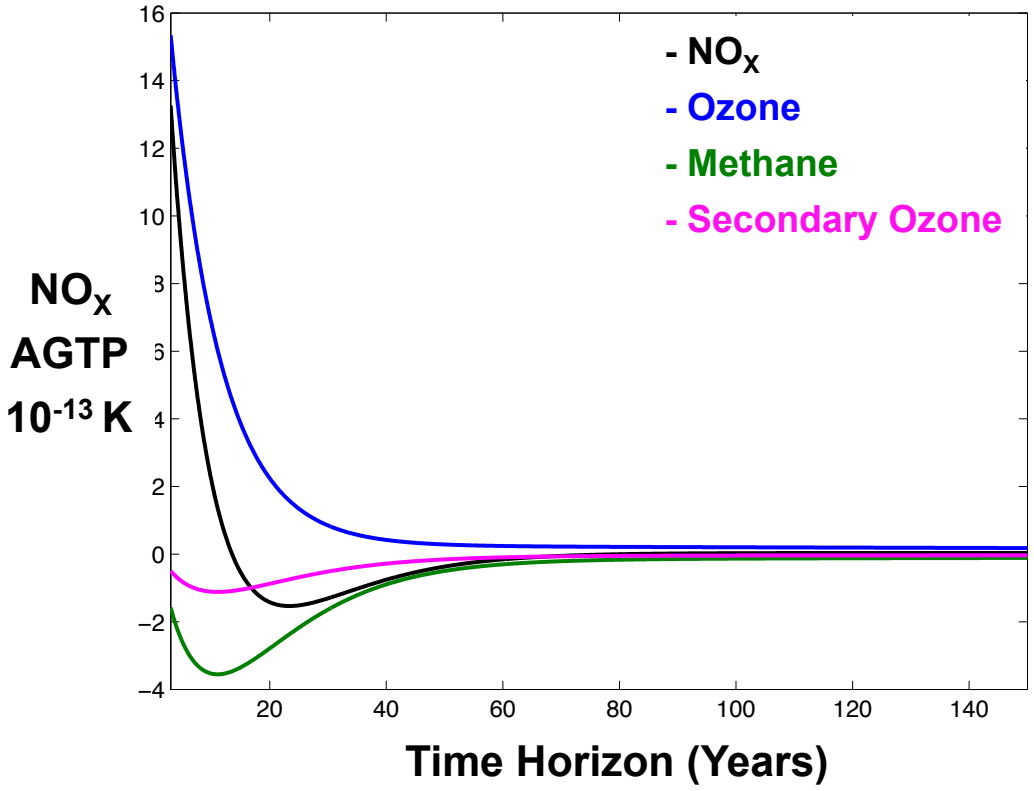
- Various aircraft emissions and contrails affect climate differently due to differences in their lifetime and interaction mechanism
- Absolute Global Temperature Change Potential (AGTP): Surface temperature change at the end of H years due to a gas, aerosol or contrails



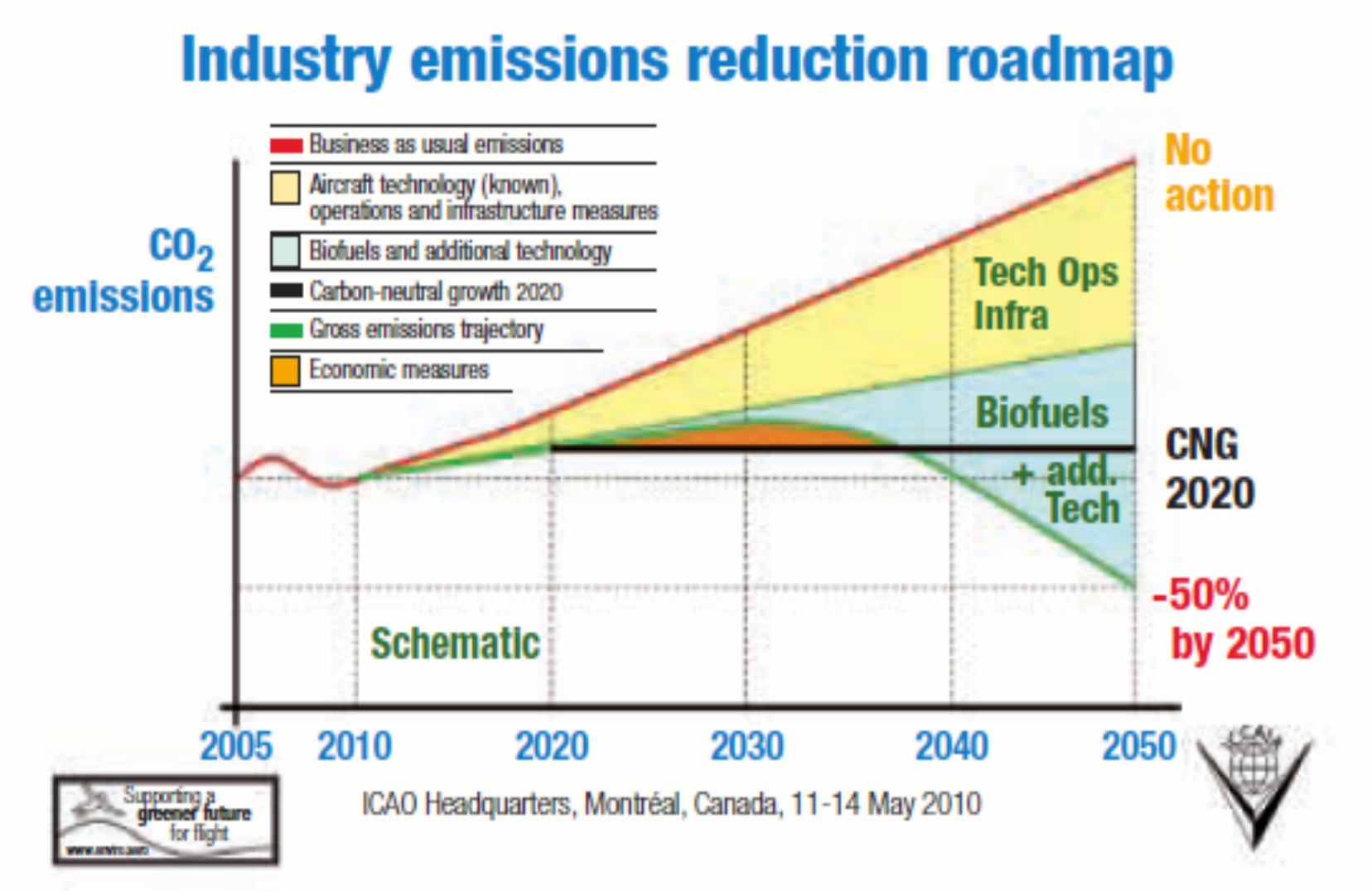
AGTP for CO_2 and NO_X

- Three components to the NO_X AGTP
  - Short-lived ozone perturbation
  - Methane perturbation
  - Methane-induced ozone perturbation

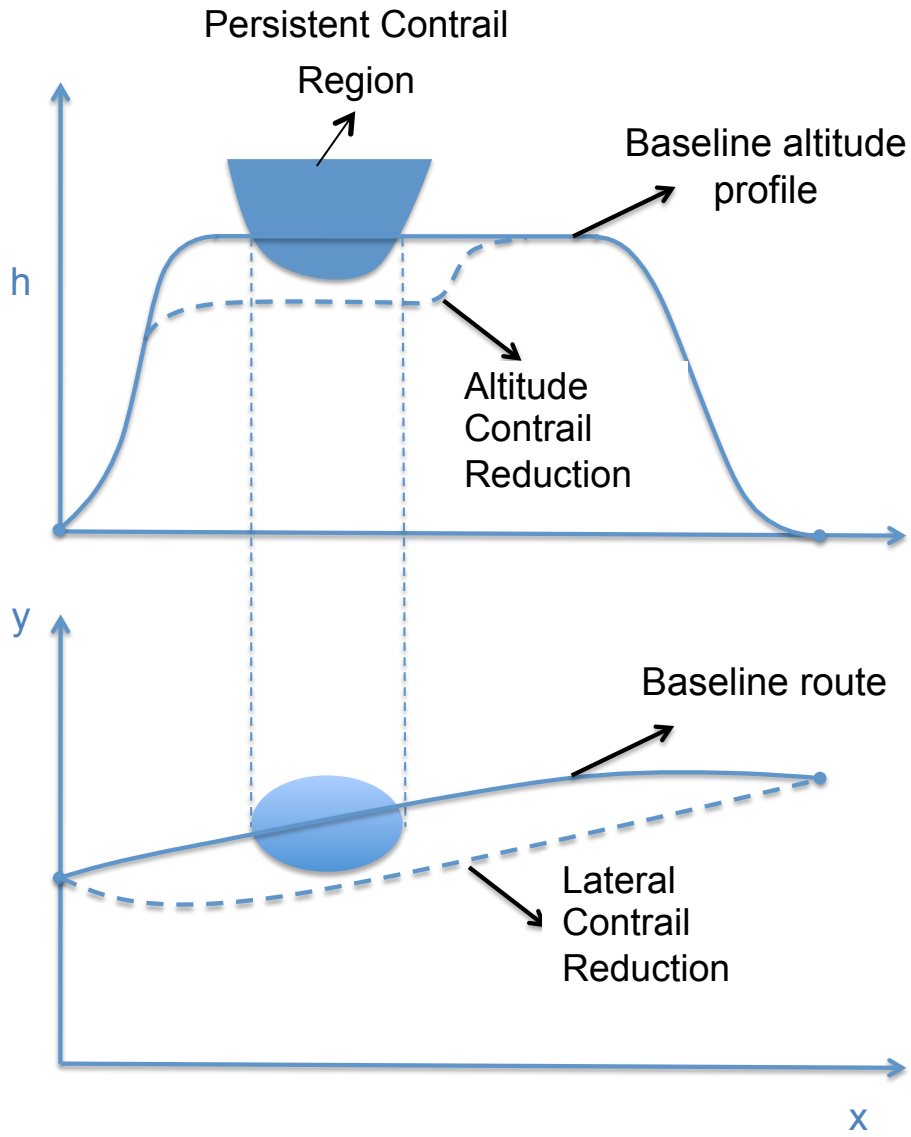




Strategies for Reducing Impact



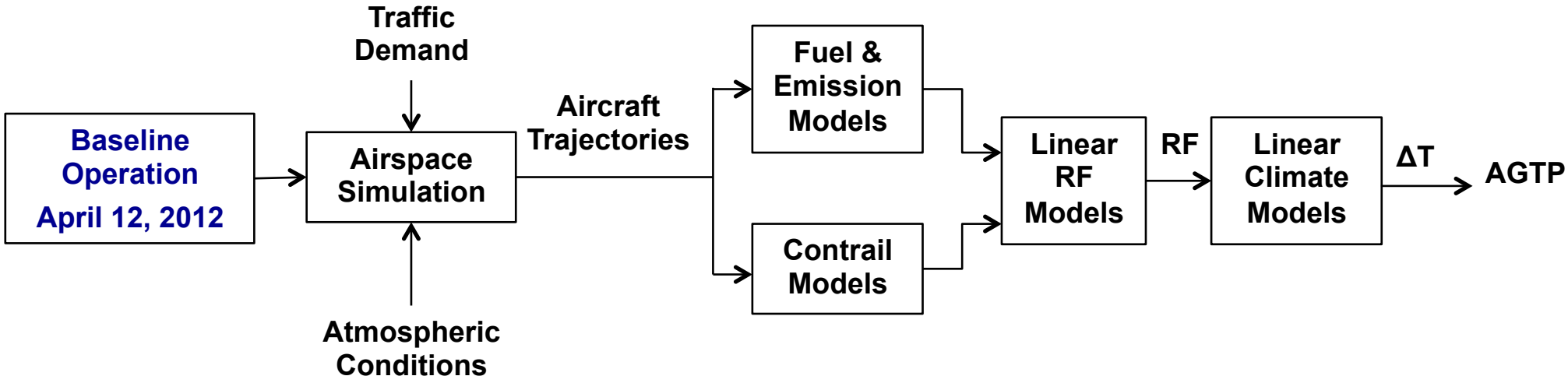
Contrail Reduction Concepts

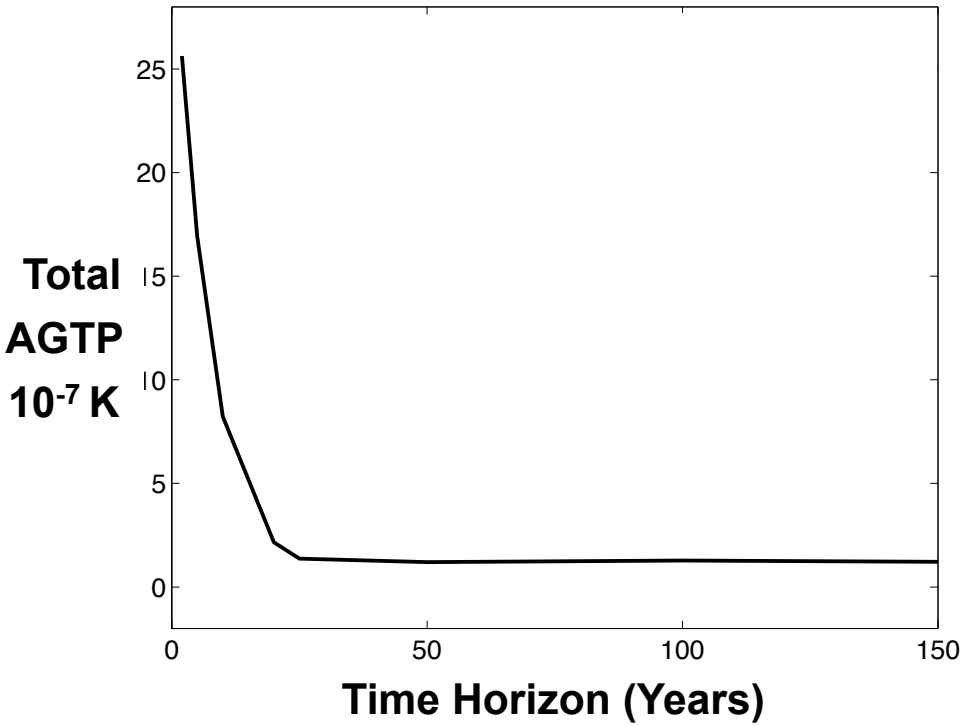


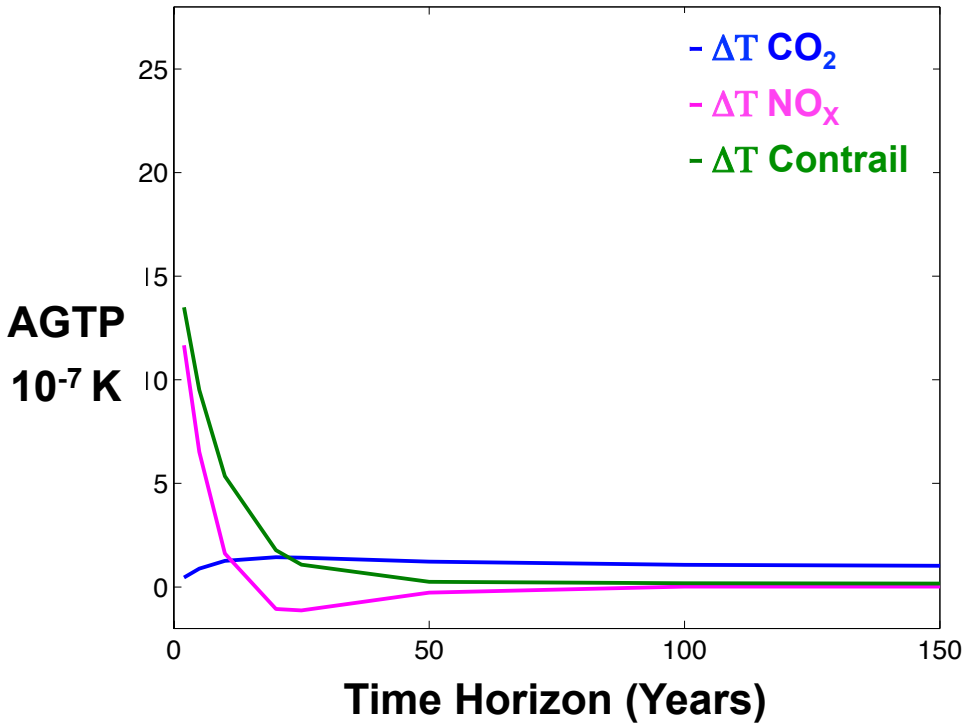
Contrail reduction using altitude changes is highly effective in reducing climate impact even in the presence of uncertainties*

***Sridhar, B., Chen, N. Y., and Ng, H. K., "Energy Efficient Contrail Mitigation Strategies for Reducing the Environmental Impact of Aviation," Tenth USA/Europe Air Traffic Management Research and Development Seminar (ATM2013), Chicago, IL, June 2013.**

AGTP (Baseline Operation)

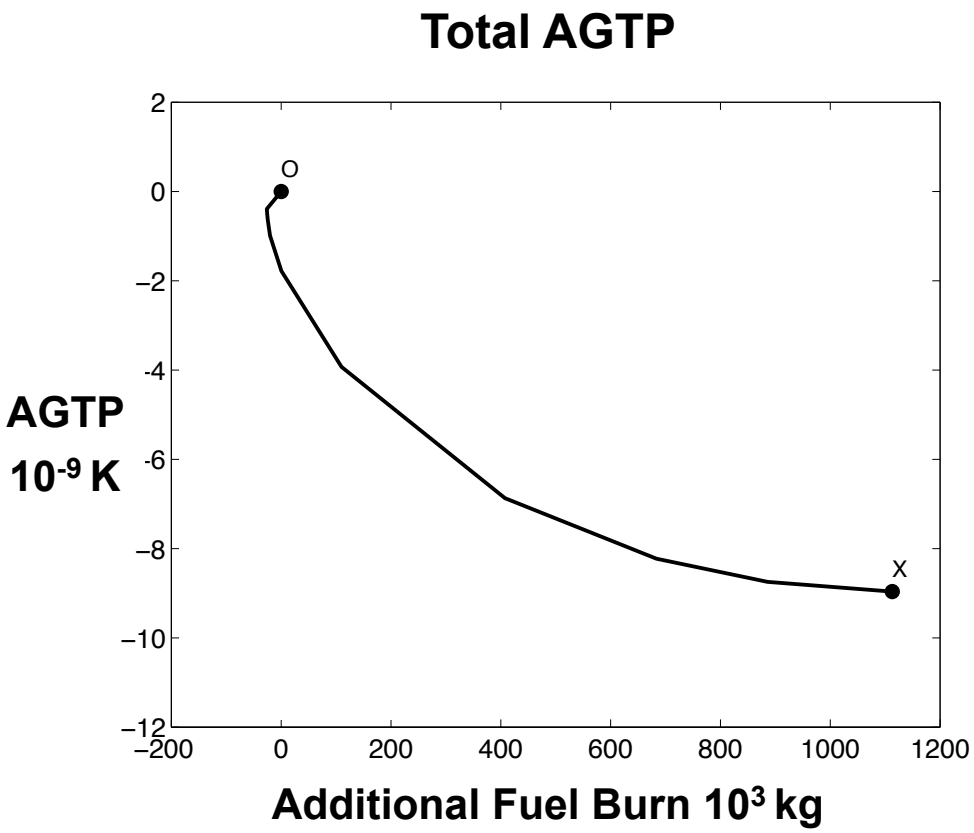


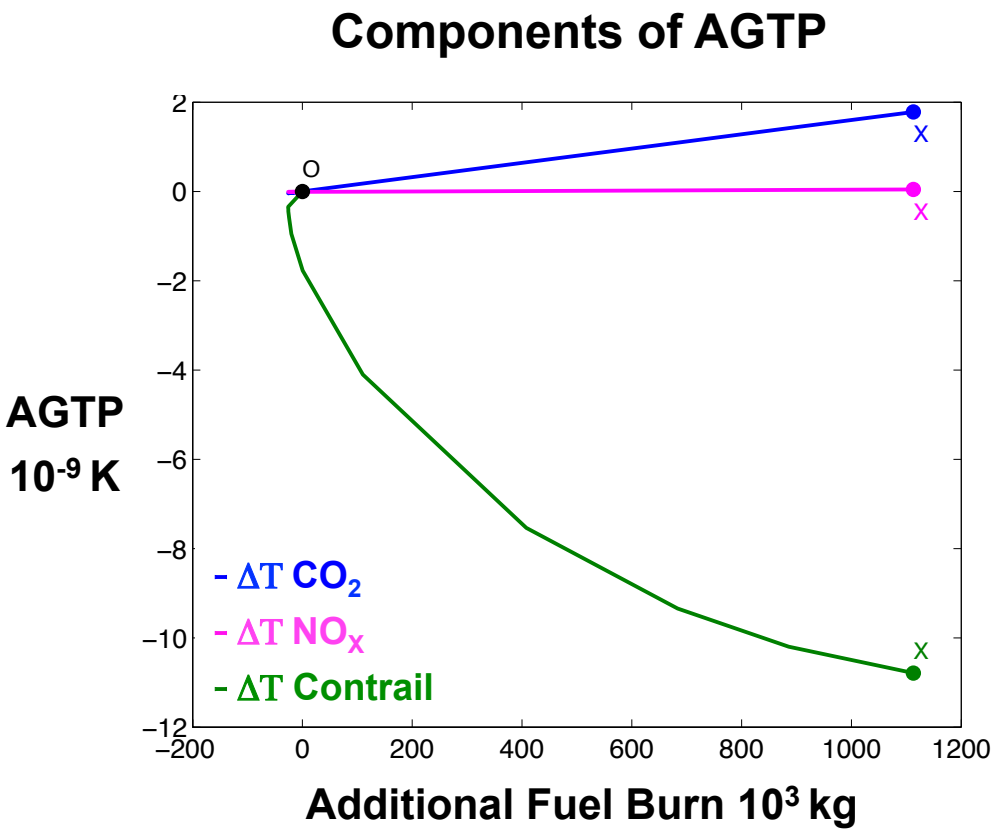




Performance of Climate Impact Reduction Strategy (H =100 Years)

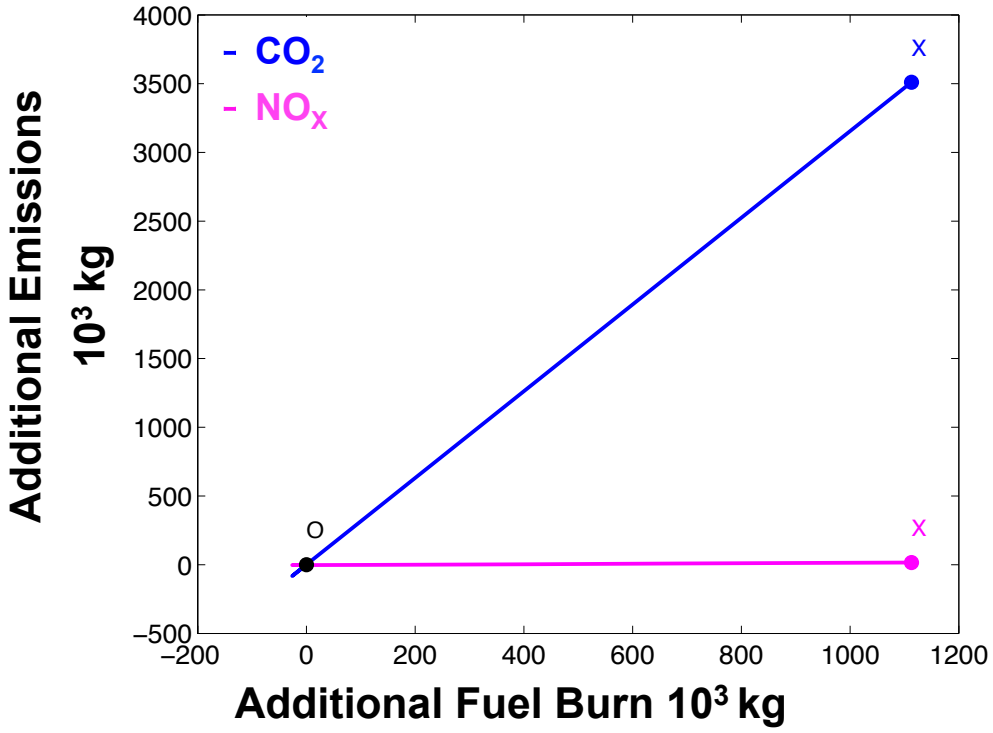
- Compute AGTP for baseline operation (O)
- Select cruise altitude providing maximum reduction in AGTP (X)
- Intermediate values generated using fuel-sensitivity index (K/kg)



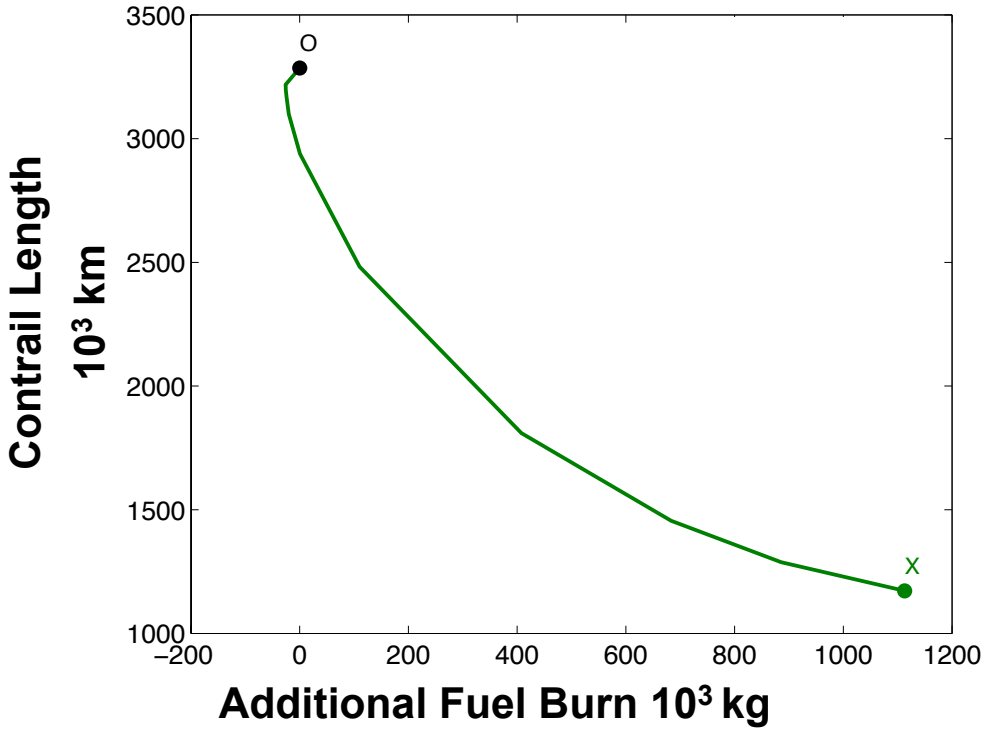


Emissions and Contrails Variation with Reduction Strategy

Variation of Emissions

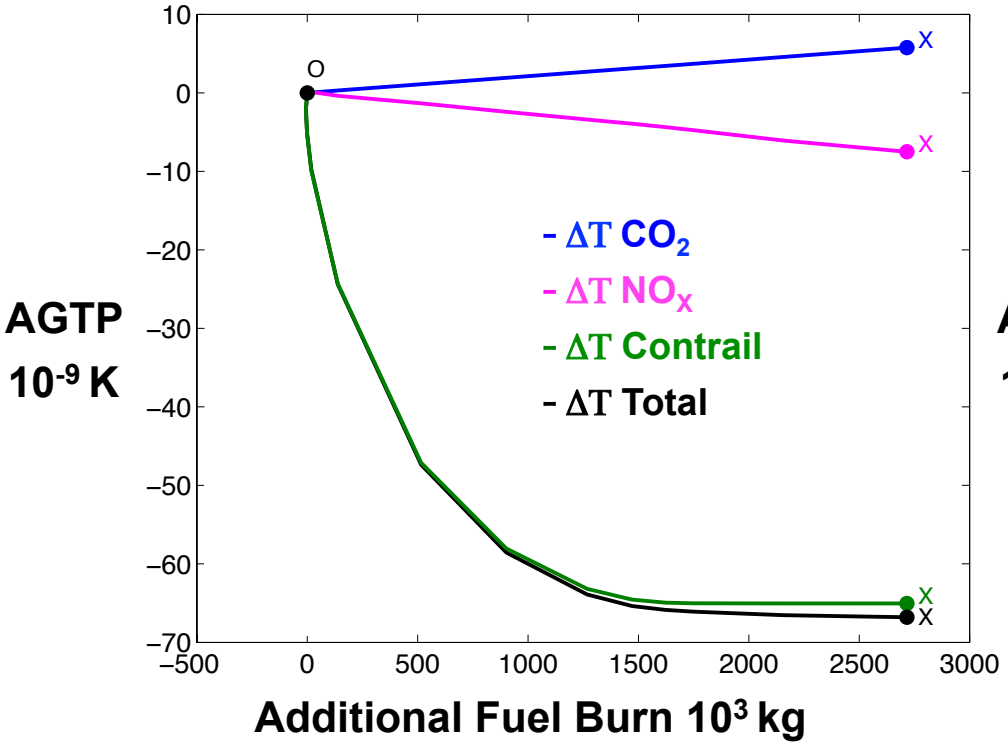


Variation of Contrails

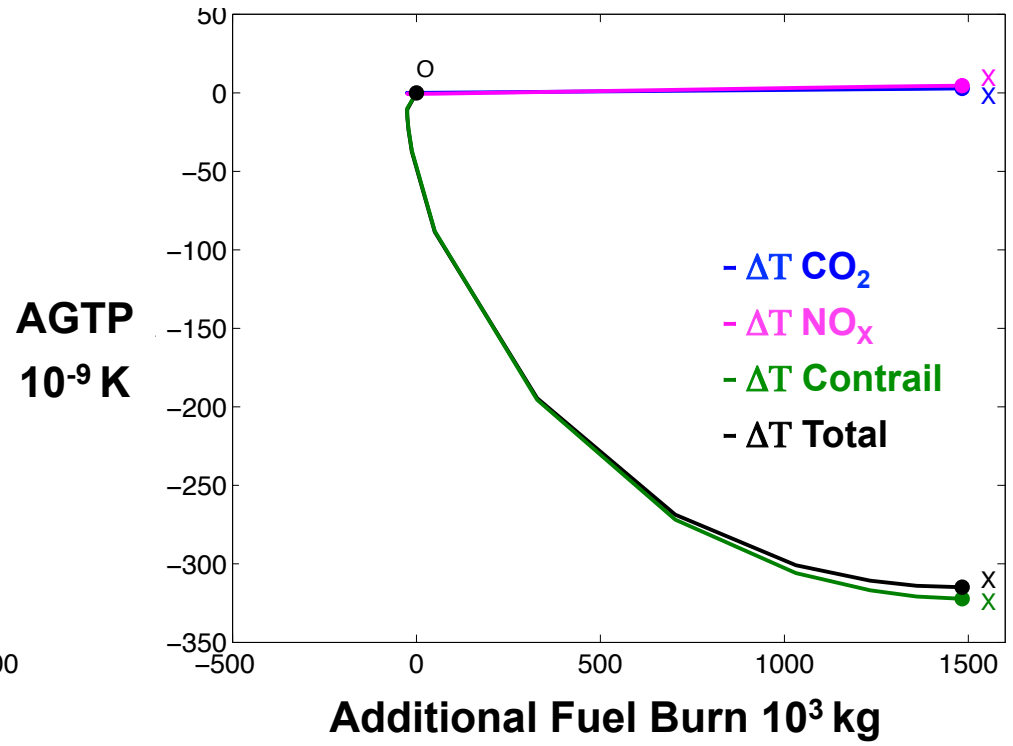


Performance Variation with Time Horizon

25 Years

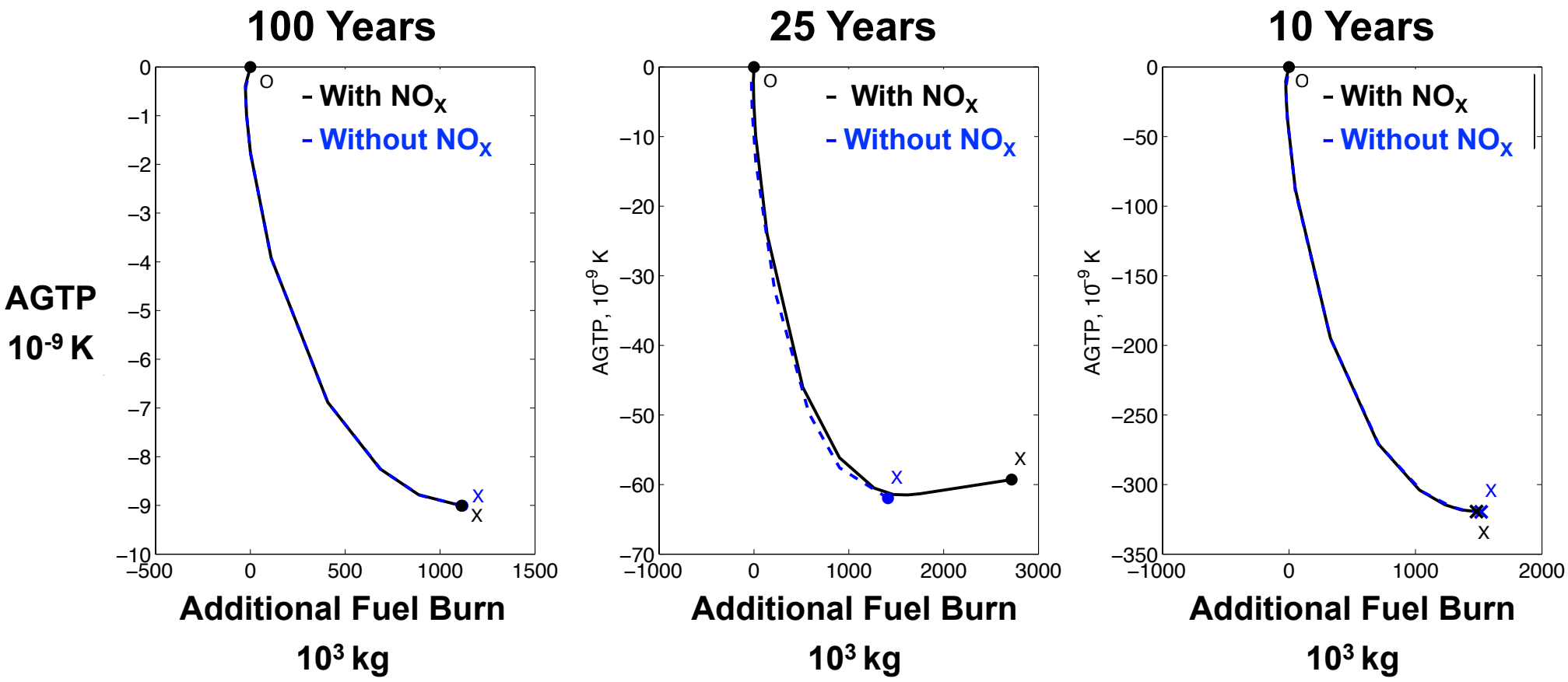


10 Years



- Most of the reduction in AGTP comes from reducing the effect of contrails
- Effect of contrails decreases as time horizon increases (300x10^{-9}K for 10 years to 9x10^{-9}K for 100 years)

Effect of NO_X on AGTP



Concluding Remarks

- Developed energy efficient strategies to reduce the combined environmental effect of CO_2, NO_X and contrails
  - Effect of NO_X is negligible except for a small impact around 25 years
  - Effect of contrails decreases as time horizon increases
- Developed capability to conduct system level analysis of Air Traffic Management concepts with environmental impact